PROGRAMMED INSTRUCTION

BASIC F-M RECEIVER THEORY

X-5B

Naval Air Technical Training Command

CNATT-M151 PAT

OBJECTIVES

X-5B—Basic F-M Receiver Theory

The student will:

1. List the minimum acceptable signal-to-noise ratios for f-m and a-m receivers. (9)
2. State two causes of the many problems inherent in commercial f-m receivers. (13)
3. Write the three methods used to broaden the bandpass of the i-f amplifiers in an f-m receiver.(15)
4. Name the section of an f-m receiver that is markedly different from an a-m receiver. (16)
5. State the purpose of a discriminator. (25)
6. Given four statements, select two that describe the output voltage of a discriminator. (29)
7. List three discriminators used in f-m receivers. (30)
8. Write the name of the stage that must immediately precede a Foster-Seeley discriminator in an f-m receiver. (31)
9. State the characteristic of a typical limiter that clips or eliminates the positive peaks of the input signal. (39)
10. State the characteristic of a typical limiter that clips or eliminates the negative peaks of the input signal. (40)
11. Name the stage of an f-m receiver where it is possible to obtain AVC (automatic volume control) voltage. (41)
12. Given four statements, select one that describes the characteristics of the input signal to the Foster-Seeley discriminator. (50)
13. State the type of signal present in the output of the Foster-Seeley discriminator. (54)
14. State whether the tuned secondary network of a transformer is a series or parallel circuit to the input signal. (55)
15. Given a Foster-Seeley response curve, select the point that represents the output voltage when the input frequency is at the carrier rest frequency. (56)

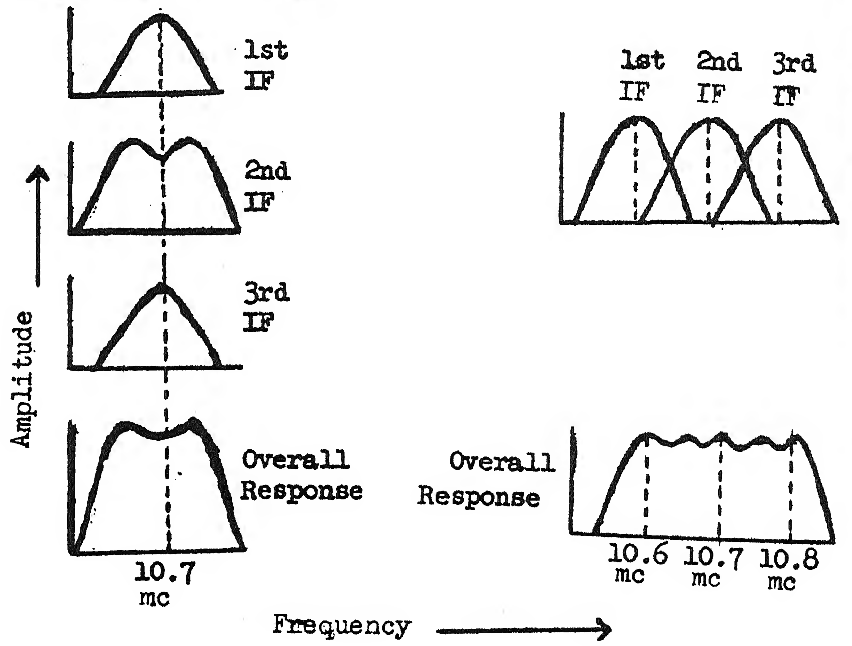
SUGGESTED READING TIME 38 MINUTES

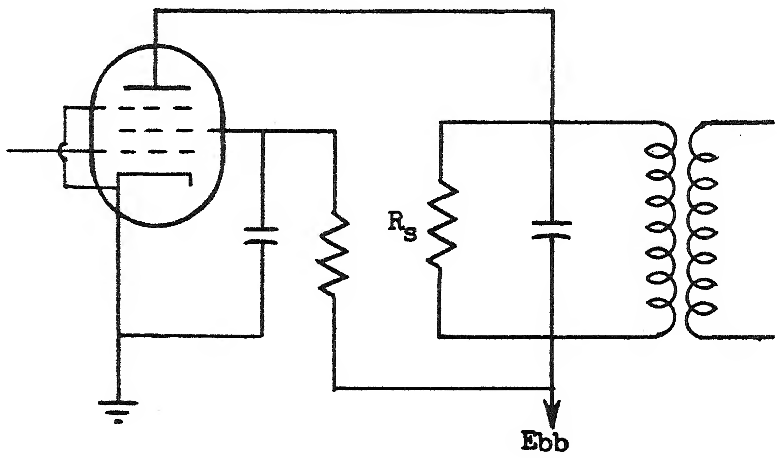
This program on f-m receivers is general in nature and refers to commercial rather than to military applications.

An f-m receiver will be compared to and contrasted with an a-m receiver which has been taught previously.

	1. Most natural and man-made noise (static) affects the amplitude of a carrier wave. In amplitude modulation, the intelligence is impressed on the carrier wave as amplitude variations. Thus, an amplitude-modulated signal is easily distorted by noise. An A-M RECEIVER must have a minimum signal-to-noise ratio of 100 to 1 to reproduce the transmitted intelligence. In frequency modulation, the intelligence is impressed on the carrier wave as frequency variations. This intelligence is not seriously affected by noise. An F-M RECEIVER needs only a minimum signal-to-noise ratio of 2 to 1 to reproduce the transmitted intelligence. Which receiver requires the higher signal-to-noise ratio, an a-m or f-m receiver? ______________________________________
An a-m receiver.	2. Match the receiver in column A to the appropriate minimum signal-to-noise ratio in column B. Column A — Column B ____ 1. F-m receiver — a. 100 to 1 ____ 2. A-m receiver — b. 50 to 1 c. 2 to 1

1. c 2. a	3. There are two causes of the many problems inherent in commercial f-m receivers: (1) f-m receivers operate at VHF (very high frequency); (2) f-m receivers require a broad bandpass. Circuits designed to operate in the VHF range contain small components. Stray-wire capacitance and lead inductance can seriously affect circuit characteristics. Also, oscillator stability is difficult to attain. Higher modulating frequencies (up to 15 kc) are used in f-m than in a-m; thus, the bandwidth required in an f-m receiver can be as high as 150 kc. The coupling circuits in an f-m receiver must have a broad bandpass to pass these frequencies. The commercial f-m receiver operates at VHF, and it requires a ________________ bandpass.
broad	4. Select two causes of the many problems inherent in commercial f-m receivers. (1) They operate at SHF. (2) They operate at VHF. (3) They require a narrow bandpass. (4) They require a broad bandpass.

2 and 4	5. What are the minimum acceptable signal-to-noise ratios for f-m and a-m receivers? a. F-m receiver: ________________ b. A-m receiver: ________________
a. 2 to 1 b. 100 to 1	6. The i-f amplifiers of an f-m receiver must pass a broad band of frequencies (up to 150 kc in width). <u>Overcoupling</u>, <u>stagger tuning</u>, and <u>swamping</u> are utilized to broaden the i-f bandpass. The effect on the bandpass of <u>overcoupling</u> is shown in figure 6-1 and of <u>stagger tuning</u> in figure 6-2. Both methods result in broader bandpass. (10.7 mc is the commercial i-f frequency.)  Figure 6-1 Figure 6-2 Continue to next page.

	6. (Continued) Three methods used to broaden the bandpass of i-f amplifiers are: by swamping, by overcoupling, and by ______________ ______________.
stagger tuning	7.  Figure 7 OVERCOUPLING and STAGGER TUNING are two methods used to broaden the i-f bandpass. The third method used is SWAMPING. NOTE: When a resistor is connected in parallel with a tuned circuit, the circuit is said to be "swamped." That is, the resistor absorbs power from the tuned circuit, lowering its Q. As shown in figure 7, the swamping resistor (R_s) is placed in parallel with the parallel LC circuit (i-f transformer).

7. (Continued)

Bandwidth can be calculated by using the formula

$$BW = \frac{F_r}{Q}$$

where BW = bandwidth,

F_r = resonant frequency,

Q = figure of merit.

The formula for "Q" of the circuit is expressed as

$$Q = \frac{R_s}{X_L}$$

where "Q" = figure of circuit merit,

R_s = shunt or SWAMPING resistance,

X_L = inductive reactance.

Thus, as the resistance of R_s decreases, circuit "Q" decreases and bandwidth increases.

★ NOTE: The formula for circuit "Q" is the reciprocal of the formula for coil or inductor "Q." The circuit "Q" is determined primarily by the parallel resistance (R_s), and the coil "Q" is determined by the series d-c resistance of the coil.

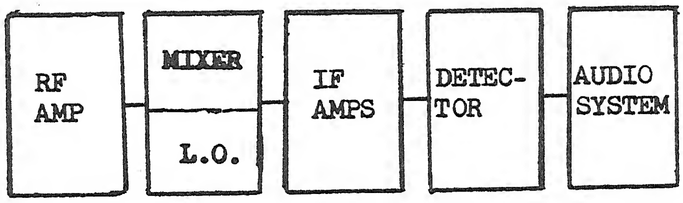
Continue to next page.

	7. (Continued) What three methods are used to broaden the bandpass of the i-f amplifiers in an f-m receiver? a. Undercoupling, stagger tuning, and swamping. b. R-C coupling, stagger tuning, and overcoupling. c. Overcoupling, stagger tuning, and swamping. d. Impedance coupling, swamping, and undercoupling.
c.	8. Two causes of the many problems inherent in commercial f-m receivers are (1) they operate at VHF; (2) they ______________________________
(2) require a broad bandpass.	9. What are the minimum acceptable signal-to-noise ratios for f-m and a-m receivers? a. F-m receiver: ________________ b. A-m receiver: ________________

a. 2 to 1

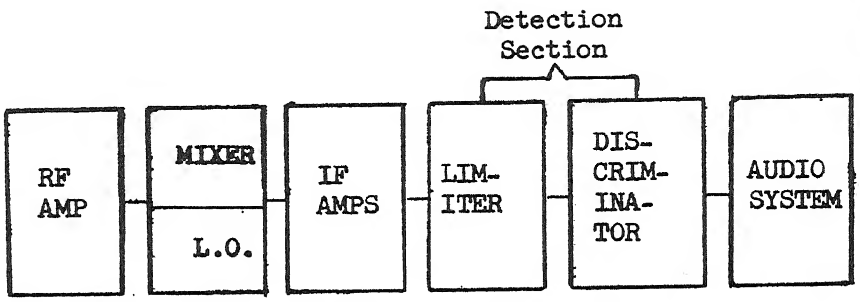
b. 100 to 1

10.



A-M Receiver

Figure 10-1



F-M Receiver

Figure 10-2

Receiver Block Diagrams.

The block diagrams above represent an a-m (amplitude-modulated) and an f-m (frequency-modulated) receiver. Although some differences have been mentioned in this program, the r-f amplifiers, the mixers, the i-f amplifiers, and the audio systems are basically similar in both receivers. Both receivers employ detectors to remove the intelligence from the carrier wave, but the DETECTION SECTION of the f-m receiver is markedly different from that of the a-m receiver.

The section of an f-m receiver which is markedly different from that of an a-m receiver is called the

________________ section.

detection	11. Compare the sections of an f-m receiver and an a-m receiver. Write "S" for similar and "D" for different in the space provided. a. ____ R-f amplifier section. b. ____ Mixer section. c. ____ I-f amplifier section. d. ____ Detection section.
a. S b. S c. S d. D	12. Three methods used to broaden the bandpass of the i-f amplifiers in an f-m receiver are: (1) Overcoupling. (2) ____________________. (3) ____________________.
(2) Stagger-tuning (3) Swamping	13. List two causes of the many problems inherent in commercial f-m receivers. (1) ____________________ (2) ____________________
(1) They operate at VHF. (2) They require broad bandpass.	14. The section of an f-m receiver that is markedly different from an a-m receiver is ______________________________.

the detection section.	15. Write three methods used to broaden the bandpass of the i-f amplifiers in an f-m receiver. (1) ____________________ (2) ____________________ (3) ____________________
(1) Over-coupling. (2) Stagger tuning. (3) Swamping.	16. What section of an f-m receiver is markedly different from that of an a-m receiver? ______________________________
The detection section.	17. The DISCRIMINATOR in an f-m receiver <u>demodulates</u> or detects the f-m signal; that is, it separates the intelligence from the r-f carrier. The input to a discriminator is an r-f carrier wave that has been frequency-modulated by an audio signal. The discriminator produces an audio-signal output. An f-m signal is detected or demodulated by a ____________________.
discriminator	18. What is the purpose of a discriminator? a. It amplifies and distorts the f-m signal. b. It modulates the f-m signal. c. It demodulates or detects the f-m signal.

c.	19. The function of the discriminator is to demodulate or detect an f-m signal. To explain this function, it is necessary to know the characteristics of the output voltage. The <u>output voltage is dependent upon input frequency</u>. When the input remains fixed at f_o (<u>carrier rest frequency</u>), <u>the output is zero volts</u>. If the input frequency varies above and below the center frequency at an audio rate, the output voltage will vary positive and negative at an audio rate. If the input frequency remains fixed at f_o (carrier rest frequency), the discriminator output voltage is ________________. (zero/positive/negative)
zero	20. The output voltage of a discriminator is dependent upon input ________________. (frequency/voltage) When the input frequency is at f_o (carrier rest frequency), the output voltage is ________________. (positive/negative/zero)
frequency zero	21. What is the purpose of a discriminator? ________________________________ ________________________________

To de-modulate or detect the f-m signal.	22. There are three f-m discriminators in general use: (1) the Foster-Seeley, (2) the ratio detector, and (3) the oscillator detector. The commonest discriminator is the FOSTER-SEELEY. It is often referred to as a limiter-discriminator, because it must be preceded by a limiter which clips the noise peaks of the input signal. The RATIO DETECTOR and the OSCILLATOR DETECTOR do not require limiters. The ratio detector is widely used, while the oscillator detector is rarely used. Three discriminators used in f-m receivers are: (1) the Foster-Seeley, (2) the ratio detector, and (3) the ____________ ____________.
oscillator detector	23. What are three discriminators used in f-m receivers? a. Foster-Seeley, ratio detector, and r-f detector. b. Ratio detector, oscillator detector, and r-f detector. c. Foster-Seeley, oscillator detector, and r-f detector. d. Foster-Seeley, ratio detector, and oscillator detector.
d.	24. Select two statements that describe the output voltage of a discriminator. a. It is independent of the input frequency. b. It is zero volts when the input frequency is at f_o (rest frequency). c. It is positive when the input frequency is at f_o (rest frequency). d. It is dependent upon input frequency.

b. d.	25. What is the purpose of a discriminator? ____ ____
To demodulate or detect the f-m signal.	26. In an f-m receiver, the noise (static) content is relatively large. As previously stated, however, most noise affects the <u>amplitude</u> and not the <u>frequency</u> of a carrier wave. Nevertheless, if the discriminator responds to amplitude as well as to frequency variations, the noise appears in the output. The Foster-Seeley discriminator, for example, responds to amplitude as well as to frequency variations. To eliminate the noise (amplitude) variations, a <u>limiter</u> stage must immediately precede the Foster-Seeley discriminator. Since a Foster-Seeley discriminator responds to amplitude as well as to frequency variations, it is necessary to eliminate the amplitude variations by using a ________________ stage.
limiter	27. In an f-m receiver, what stage must immediately precede a Foster-Seeley discriminator? a. A detector. b. A limiter. c. An oscillator. d. An amplifier.

b.	28. Three discriminators used in f-m receiver are (1) the Foster-Seeley, (2) the ______________________________, (3) the ______________________________.
(2) ratio detector (3) oscil-lator detector	29. Select two statements that describe the output voltage of a discriminator. a. It is dependent upon the input frequency. b. It is positive when the input frequency is at f_o (rest frequency). c. It is zero volts when the input frequency is at f_o (rest frequency). d. It is independent of the input frequency.
a. c.	30. List three discriminators used in f-m receivers. (1) ______________________________ (2) ______________________________ (3) ______________________________
(1) Foster-Seeley. (2) Ratio detector. (3) Oscil-lator detector.	31. In an f-m receiver, what stage must immediately precede a Foster-Seeley discriminator? ____________________

A limiter.

32. The POSITIVE peaks of the input signal to a typical limiter are clipped or eliminated because of plate-current (I_b) saturation. Figure 32-1 shows a schematic of a typical limiter and figure 32-2 shows an E_c (grid-voltage) vs I_b (plate-current) curve.

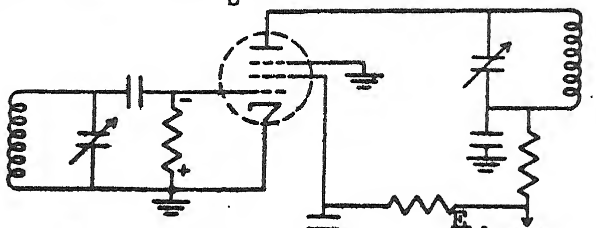


Figure 32-1

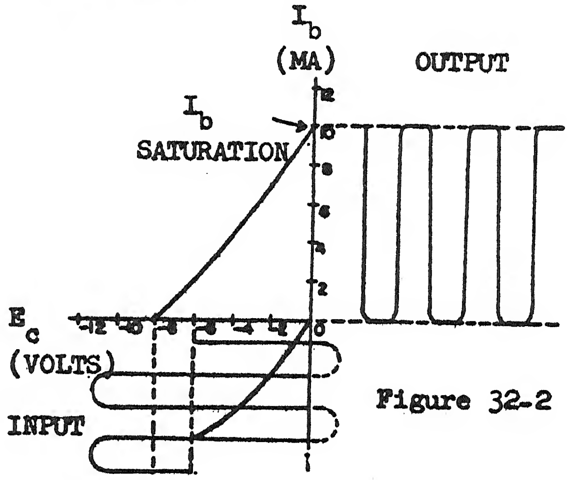


Figure 32-2

As shown in figure 32-1, plate-current saturation is easily achieved by using relatively low plate and screen-grid voltages. Figure 32-2 shows the input signal varying around a bias of -6 volts. As the input signal goes positive, plate current increases, plate voltage decreases, and plate-current saturation is attained, thereby eliminating POSITIVE peaks of the input signal.

Positive peaks of the input signal are eliminated or clipped because of plate-current ______________
(saturation/ cutoff)

saturation

33. The NEGATIVE peaks of the input signal to a typical limiter are clipped or eliminated because of <u>plate-current</u> (I_b) <u>cutoff.</u>

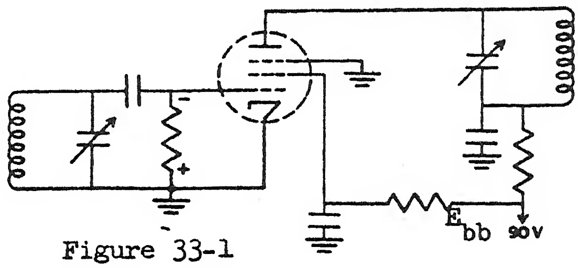


Figure 33-1

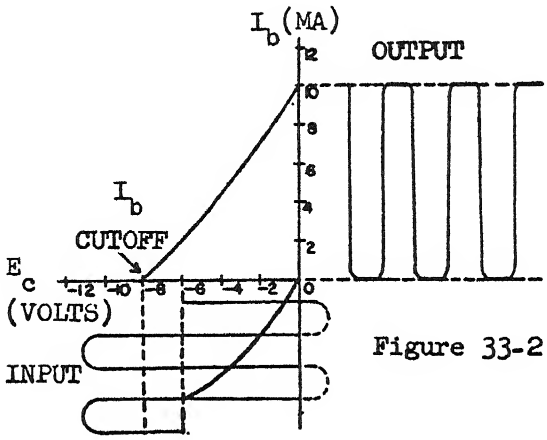


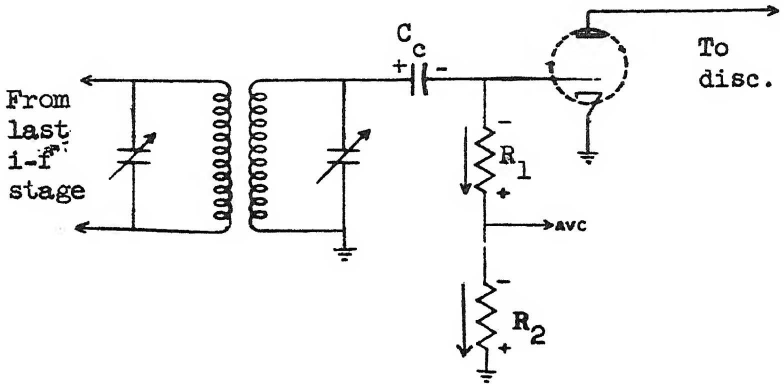
Figure 33-2

As shown in the schematic diagram, figure 33-1, the cathode is at ground and the bias is zero in a static state. Figure 33-2 shows the bias increasing to -6 volts as an input signal is applied. Plate-current cutoff is achieved when the grid voltage reaches -8 volts. As the input signal swings negative, plate-current cutoff is reached, thereby eliminating NEGATIVE peaks of the input signal.

Negative peaks of the input signal are eliminated or clipped because of plate-current ______________
(saturation/cutoff)

cutoff	34. What characteristic of a typical limiter clips or eliminates the positive peaks of the input signal? a. Plate-current saturation. b. Grid-current saturation. c. Plate-current cutoff. d. Grid-current cutoff.
a.	35. In a typical limiter, negative peaks of the input signal are eliminated by a. plate-current saturation. b. plate-current cutoff. c. using a high plate voltage. d. using a high plate current.
b.	36. What characteristic of a typical limiter clips or eliminates the <u>positive peaks</u> of the input signal? __________________________________

Plate-current saturation.	37. In addition to limiting the positive and negative peaks of the input signal, a LIMITER can be used to obtain an AVC (automatic volume control) voltage.



Limiter Stage Showing a
Method of Obtaining AVC Voltage

Figure 37

Referring to figure 37, the input signal from the last i-f stage is coupled to the grid of the limiter. As the grid signal goes in a positive direction, grid current is drawn, charging capacitor C_c. The RC time of C_c, R_1, and R_2 is long to the input signal. A negative d-c voltage is developed across R_1 and R_2 by the discharge of C_c. The amount of this negative voltage varies directly as the amplitude of the input signal varies, thus providing an AVC voltage. The amount of the available negative voltage used as AVC depends upon the resistance of R_1 as compared to R_2.

An AVC (automatic volume control) voltage can be obtained from a ________________ stage.

limiter	38. In an f-m receiver, which of the following stages can be used to obtain an AVC voltage? a. Mixer b. Amplifier c. Limiter
c.	39. What characteristic of a typical limiter clips or eliminates the positive peaks of the input signal? ________________________________
Plate-current saturation.	40. What characteristic of a typical limiter clips or eliminates the negative peaks of the input signal? ________________________________
Plate-current cutoff.	41. What stage of an f-m receiver can be used to obtain an AVC (automatic volume control) voltage? ________________
The limiter.	42. The Foster-Seeley discriminator has an input signal that is constant in amplitude and varying in frequency. To ensure that the amplitude of the input signal is constant, a limiter circuit is always placed immediately before a Foster-Seeley discriminator to eliminate the positive and negative peaks. A frequency-modulated signal is varying in frequency because this is the method used to impress intelligence upon the carrier wave. The input signal to a Foster-Seeley discriminator has a __________ (constant/varying) amplitude and __________ (constant/varying) frequency.

constant varying	43. Select the statement that describes the characteristics of the input signal to a Foster-Seeley discriminator. a. Frequency constant; amplitude varying. b. Amplitude varying; frequency varying. c. Frequency constant; amplitude constant. d. Amplitude constant; frequency varying.
d.	44. The output of a Foster-Seeley discriminator is an <u>audio signal</u>. The input is an r-f signal with a constant amplitude and varying in frequency at an audio rate. The output voltage is varying in amplitude at an audio rate. The output of a Foster-Seeley discriminator is an ________________ signal.
audio	45. Select the statement that describes the output signal of a Foster-Seeley discriminator. a. An r-f signal. b. A video signal. c. An audio signal.
c.	46. Describe the amplitude and frequency of the input signal to a Foster-Seeley discriminator. a. Amplitude ________________ b. Frequency ________________

a. constant

b. varying

47. The operation of a Foster-Seeley discriminator is based upon the principle of a tuned-secondary transformer network, as shown in figure 47-1. Capacitor C_2 and inductor L_2 form a SERIES CIRCUIT to the input voltage, E_{ind}. At resonance (figure 47-2), the circuit is resistive; secondary current (I_{sec}) is in phase with the induced voltage (E_{ind}). Above resonance (figure 47-3), the circuit is inductive; I_{sec} lags E_{ind}. Below resonance (figure 47-4), the circuit is capacitive; I_{sec} leads E_{ind}.

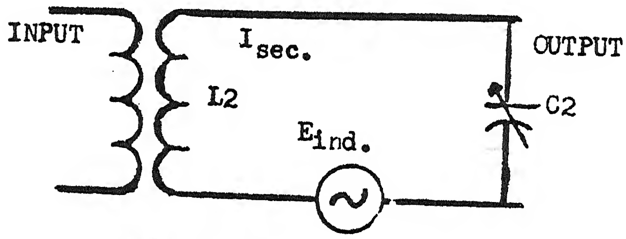
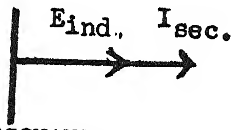
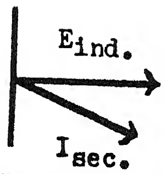


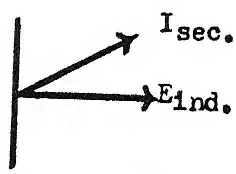
Figure 47-1



AT RESONANCE
Figure 47-2



ABOVE RESONANCE
Figure 47-3



BELOW RESONANCE
Figure 47-4

Continue to next page.

	47. (Continued) To the input signal, the tuned-secondary network of a transformer is a ______________ circuit. (series/parallel)
series	48. Which statement describes how the tuned-secondary network of a transformer appears to the input signal? a. As a parallel circuit. b. As a series-parallel circuit. c. As a series circuit.
c.	49. What type of signal is present in the output of the Foster-Seeley discriminator? ______________________________
An audio signal.	50. Select the statement that describes the characteristics of the input signal to a Foster-Seeley discriminator. a. Amplitude constant; frequency varying. b. Frequency constant; amplitude varying. c. Amplitude varying; frequency varying. d. Amplitude constant; frequency constant.

a.	51. The output voltage of a Foster-Seeley discriminator is dependent upon variations of input frequency. In figure 51-1, L_2, L_3, and C_2 form a circuit which is tuned to the carrier rest frequency (f_o). The output voltage is taken from the top of R_1. The voltage across V_1 is composed of $E_1 + E_2$. The voltage across V_2 is composed of $E_1 + E_3$. AT RESONANCE (figure 51-2), these voltages are equal; an equal amount of current will flow up through R_1 and down through R_2 (note arrows on figure 51-1). Voltages of equal amplitude but of opposite polarity (with respect to ground) are developed across these equal resistors and the <u>output voltage is zero</u>. ABOVE RESONANCE (figure 51-3), the voltage across V_2 ($E_1 + E_3$) is greater than the voltage across V_1 ($E_1 + E_2$); V_2 conducts more than V_1, causing a larger voltage to develop across R_2 than R_1. Thus, the output voltage is negative. BELOW RESONANCE (figure 51-4), the voltage across V_1 ($E_1 + E_2$) is greater than the voltage across V_2 ($E_1 + E_3$); V_1 conducts more than V_2, causing a larger voltage to develop across R_1 than R_2. At this time the output voltage is positive. At resonance (carrier rest frequency), the output voltage of a Foster-Seeley discriminator is ______________________ (zero/positive/negative)

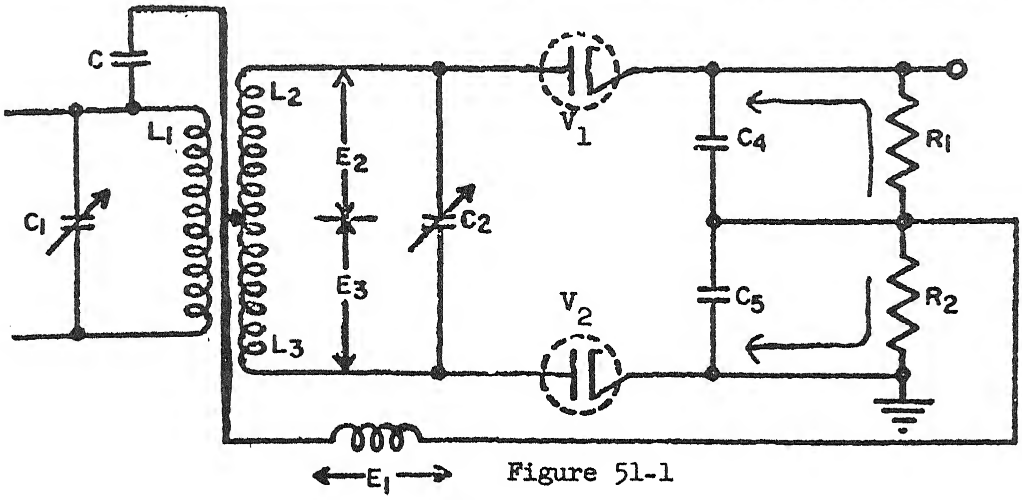
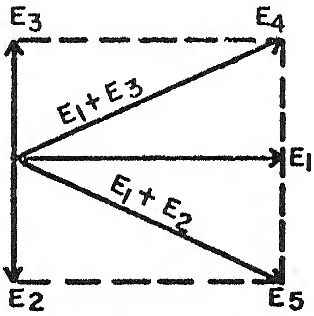
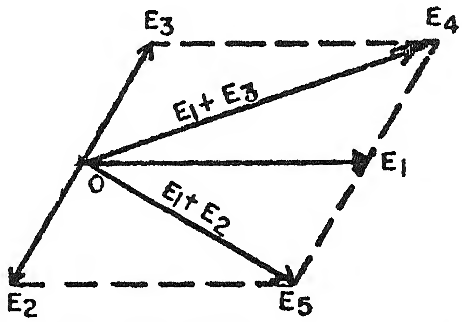


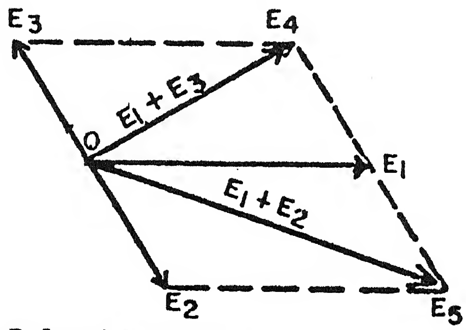
Figure 51-1



At Resonance
Figure 51-2

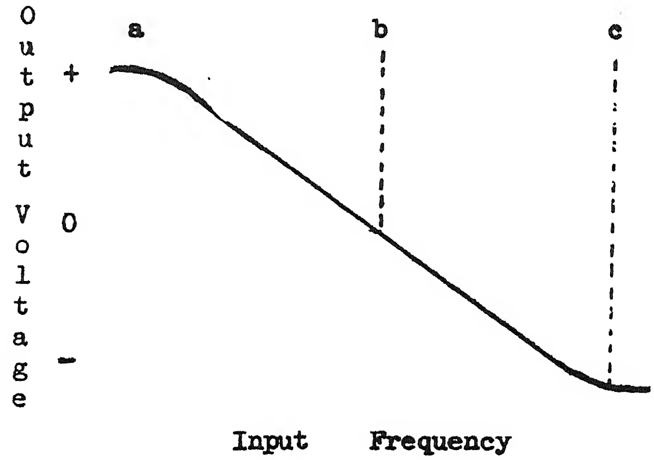


Above Resonance
Figure 51-3



Below Resonance
Figure 51-4

Foster-Seeley Discriminator Action.

zero	52. Figure 52 shows a curve representing the INPUT FREQUENCY vs the OUTPUT VOLTAGE of a Foster-Seeley discriminator. As previously explained, the output voltage varies (positive to negative) as the input frequency varies. Which point on the curve represents the output voltage when the input frequency is at the carrier rest frequency (f_o)? (Circle a, b, or c.)  Figure 52
b.	53. The tuned-secondary network of a transformer is a ______________ circuit to the input signal. (series/parallel)
series	54. What type of signal is present in the output of the Foster-Seeley discriminator? ______________
An audio signal.	55. Is the tuned-secondary network of a transformer a series or parallel circuit to the input signal? ______________

A series circuit.

56. Figure 56 shows a curve representing the INPUT FREQUENCY vs the OUTPUT VOLTAGE of a Foster-Seeley discriminator. Which point on the curve represents the output voltage of the discriminator when the input frequency is at the carrier rest frequency (f_o)? (Circle a, b, or c.)

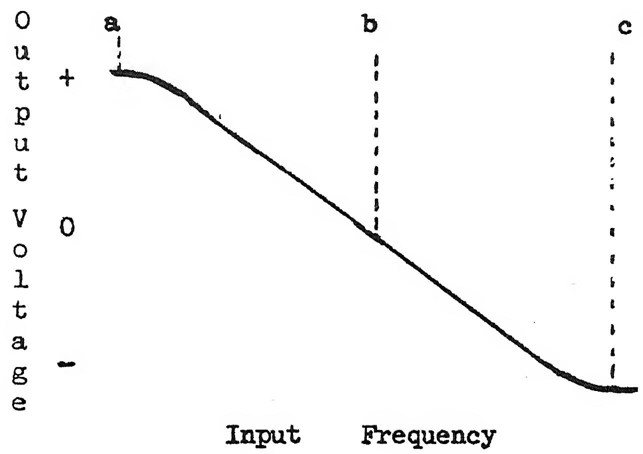


Figure 56

b.

You have completed this program. Review the objectives at the front of this booklet. If you do not understand them, turn to the frames indicated in parenthesis ( ) for clarification.

For future study in greater depth and detail, consult the following references:

a. F-M Simplified, Milton S. Kiver, D. Van Nostrand Co., Second Edition

b. F-M Transmission and Reception, Rider and Uslan, Rider Publications

X-5B
BASIC F-M RECEIVER THEORY
REVIEW TEST

NAME ______________________ RATE __________ CLASS ________ DATE ____________

1. What are the minimum acceptable signal-to-noise ratios for f-m and a-m receivers?

   a. F-m ________________

   b. A-m ________________

2. List two causes of the many problems inherent in commercial f-m receivers.

   (1) ____

   (2) ____

3. Write three methods used to broaden the bandpass of the i-f amplifiers in an f-m receiver.

   (1) ______________________________

   (2) ______________________________

   (3) ______________________________

4. What section of an f-m receiver is markedly different from an a-m receiver?

   ____

5. What is the purpose of a discriminator?

   ____

6. Select two statements that describe the output voltage of a discriminator.

   a. It is dependent upon the input frequency.

   b. It is positive when the input frequency is at f_o (rest frequency).

   c. It is zero volts when the input frequency is at f_o (rest frequency).

   d. It is independent of the input frequency.

7. List three discriminators used in f-m receivers.

(1) ____________________

(2) ____________________

(3) ____________________

8. In an f-m receiver, what stage must immediately precede a Foster-Seeley discriminator?

____

9. What characteristic of a typical limiter clips or eliminates the positive peaks of the input signal?

____

10. What characteristic of a typical limiter clips or eliminates the negative peaks of the input signal?

____

11. What stage of an f-m receiver can be used to obtain an AVC (automatic volume control) voltage?

____

12. Select the statement that describes the characteristics of the input signal to a Foster-Seeley discriminator.

a. Amplitude constant; frequency varying.

b. Frequency constant; amplitude varying.

c. Amplitude varying; frequency constant.

d. Frequency constant; amplitude constant.

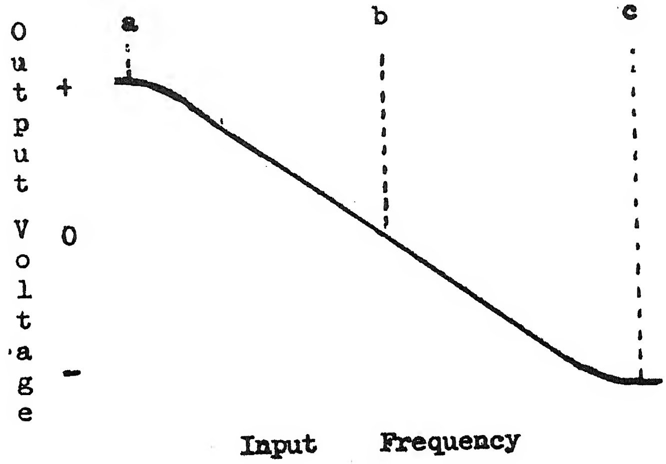
13. What type of signal is present in the output of the Foster-Seeley discriminator?

____

14. Is the tuned-secondary network of a transformer a series or parallel circuit to the input signal?

____

15. The drawing below shows a curve representing the INPUT FREQUENCY vs the OUTPUT VOLTAGE of a Foster-Seeley discriminator. Which point on the curve represents the output voltage of the discriminator when the input frequency is at the carrier rest frequency (f_o)? (Circle a, b, or c.)



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